

CLAIMS

What is claimed is:

1. A gas-expansion cooler assembly having an assembly axis and comprising:
  - an expansion plate having
    - an expansion orifice therein, wherein the expansion orifice has an expansion-orifice inlet and an expansion-orifice outlet, and
    - an expansion-plate axial channel extending through the expansion plate parallel to the assembly axis;
    - an end plate in facing relation to a first side of the expansion plate, wherein the expansion plate and the end plate together define an expansion reservoir in fluid-flow communication with the expansion-orifice outlet and in fluid-flow communication with the expansion-plate axial channel; and
    - a heat exchanger in facing relation to a second side of the expansion plate and having
      - a heat-exchanger inlet, and
      - a heat-exchanger outlet in fluid-flow communication with the expansion orifice inlet,
  - wherein the heat exchanger comprises at least two heat-exchanger plates stacked in a facing relationship along the assembly axis, and wherein each heat-exchanger plate includes
    - an in-plane channel lying substantially in a plane perpendicular to the assembly axis, wherein the in-plane channels in two adjacent heat-exchanger plates are in fluid-flow communication with each other, wherein an expansion-end heat-exchanger plate adjacent to the expansion plate has the in-plane channel in fluid-flow communication with the expansion-orifice inlet, and wherein an inlet-end heat-exchanger plate remote from the expansion plate has the in-plane channel in fluid-flow communication with the heat-exchanger inlet, whereby the in-plane channels of the heat-exchanger plates form a continuous high pressure fluid-flow path from the heat-exchanger inlet to the expansion-orifice inlet; and

an axial channel extending parallel to the assembly axis, wherein  
30 the respective axial channels in two adjacent heat-exchanger plates are in fluid-  
flow communication with each other, and wherein the expansion-end heat-  
exchanger plate has the axial channel in fluid-flow communication with the  
expansion-plate axial channel, whereby the expansion reservoir and the axial  
channels in the expansion plate and the heat-exchanger plates form a continuous  
35 exhaust fluid-flow path from the expansion-orifice outlet to an exhaust port.

2. The gas-expansion cooler assembly of claim 1, wherein the in-plane  
channel is a spiral.

3. The gas-expansion cooler assembly of claim 1, wherein there is  
exactly one in-plane channel and a plurality of axial channels in each heat-  
exchanger plate.

4. The gas-expansion cooler assembly of claim 1, wherein the heat-  
exchanger plates are made of silicon.

5. The gas-expansion cooler assembly of claim 1, further including  
a cooled device in thermal contact with the end plate.

6. The gas-expansion cooler assembly of claim 1, further including  
a cooled device in thermal contact with the end plate, wherein the cooled  
device is formed in and is integral with the end plate.

7. The gas-expansion cooler assembly of claim 1, wherein all of the  
heat-exchanger plates are substantially identical in construction.

8. The gas-expansion cooler assembly of claim 1, further including  
an insulator-seal plate between each of the heat-exchanger plates and  
between the expansion-end heat-exchanger plate and the expansion plate.

9. The gas-expansion cooler assembly of claim 1, further including an insulator-seal plate between each of the heat-exchanger plates and between the expansion-end heat-exchanger plate and the expansion plate, wherein all of the insulator-seal plates are substantially identical in construction.

10. The gas-expansion cooler assembly of claim 1, further including a polytetrafluoroethylene insulator-seal plate between each of the heat-exchanger plates and between the expansion-end heat-exchanger plate and the expansion plate.

11. The gas-expansion cooler assembly of claim 1, further including an anti-plugging structure that prevents plugging of the expansion orifice by solid matter.

12. A gas-expansion cooler assembly having an assembly axis and comprising:

an expansion structure having

5 an expansion orifice with an expansion-orifice inlet and an expansion-orifice outlet, and

an expansion reservoir in fluid-flow communication with the expansion-orifice outlet; and

a heat exchanger having

a heat-exchanger inlet, and

10 a heat-exchanger outlet in fluid-flow communication with the expansion-orifice inlet,

wherein the heat exchanger comprises at least two heat-exchanger plates stacked in a facing relationship along the assembly axis, and wherein each heat-exchanger plate includes

15 an in-plane channel lying substantially in a plane perpendicular to the assembly axis, wherein the in-plane channels of the heat-exchanger plates are in fluid-flow communication with each other and with the expansion-orifice inlet to form a continuous high-pressure fluid-flow path from the heat-exchanger inlet

to the expansion-orifice inlet; and

- 20        an axial channel extending parallel to the assembly axis, wherein the axial channels in adjacent heat-exchanger plates are respectively in fluid-flow communication with each other and with the expansion reservoir to form a continuous exhaust fluid-flow path from the expansion-orifice outlet to an exhaust port.

13.        The gas-expansion cooler assembly of claim 12, wherein the heat exchanger is in facing relation to the expansion structure.

14.        The gas-expansion cooler assembly of claim 12, wherein the in-plane channel is a spiral.

15.        The gas-expansion cooler assembly of claim 12, wherein there is exactly one in-plane channel and a plurality of axial channels in each heat-exchanger plate.

16.        The gas-expansion cooler assembly of claim 12, wherein the heat-exchanger plates are made of silicon.

17.        The gas-expansion cooler assembly of claim 12, further including a cooled device in thermal contact with the expansion structure.

18.        The gas-expansion cooler assembly of claim 12, further including a cooled device in thermal contact with the expansion structure, wherein the cooled device is formed in and is integral with the expansion structure.

19.        The gas-expansion cooler assembly of claim 12, wherein all of the heat-exchanger plates are substantially identical in construction.

20.        The gas-expansion cooler assembly of claim 12, further including an insulator-seal plate between each of the heat-exchanger plates.

21. The gas-expansion cooler assembly of claim 12, further including a polytetrafluoroethylene insulator-seal plate between each of the heat-exchanger plates.

22. A method for fabricating a gas-expansion cooler assembly, comprising the steps of

preparing an expansion plate having

an expansion orifice therein, wherein the expansion orifice has an expansion-orifice inlet and an expansion-orifice outlet, and

an expansion-plate axial channel extending through the expansion plate parallel to the assembly axis;

preparing an end plate, wherein the expansion plate and the end plate together define an expansion reservoir in fluid-flow communication with the expansion-orifice outlet and in fluid-flow communication with the expansion-plate axial channel; and

preparing a heat exchanger having

a heat-exchanger inlet, and

a heat-exchanger outlet in fluid-flow communication with the expansion orifice inlet,

wherein the heat exchanger comprises at least two heat-exchanger plates stacked in a facing relationship along the assembly axis, and wherein each heat-exchanger plate includes

an in-plane channel lying substantially in a plane perpendicular to the assembly axis, wherein the in-plane channels in two adjacent heat-exchanger plates are in fluid-flow communication with each other, wherein an expansion-end heat-exchanger plate adjacent to the expansion plate has the in-plane channel in fluid-flow communication with the expansion-orifice inlet, and wherein an inlet-end heat-exchanger plate remote from the expansion plate has the in-plane channel in fluid-flow communication with the heat-exchanger inlet, whereby the in-plane channels of the heat-exchanger plates form a continuous high-pressure fluid-flow path from the heat-exchanger inlet to the expansion-orifice inlet; and an axial channel extending parallel to the assembly axis, wherein

- the axial channels in two adjacent heat-exchanger plates are respectively in fluid-flow communication with each other, and wherein the expansion-end heat-exchanger plate has the axial channel in fluid-flow communication with the expansion-plate axial channel, whereby the expansion reservoir and the axial channels in the expansion plate and the heat-exchanger plates form a continuous exhaust fluid-flow path from the expansion-orifice outlet to an exhaust port; and
- 30 assembling the gas-expansion cooler assembly by
- 35 assembling the end plate in facing relation to a first side of the expansion plate, and
- assembling the heat exchanger in facing relation to a second side of the expansion plate.

23. The method of claim 22, wherein the step of preparing the heat exchanger includes the steps of

laser micromachining the in-plane channel into at least one of the heat-exchanger plates.

24. The method of claim 23, wherein the step of preparing the heat exchanger includes the steps of

providing the heat-exchanger plates made of silicon.